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# Aerodynamic levitation of high temperature liquids

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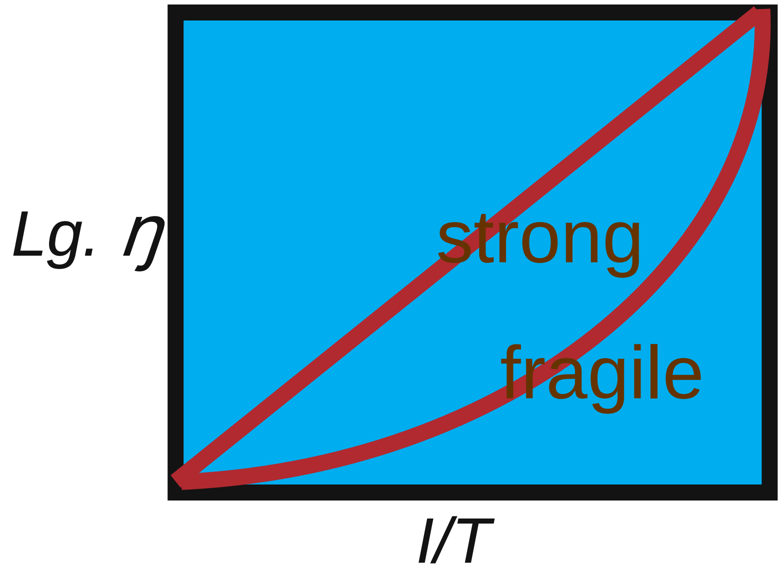
# Background/motivation

- To investigate structural evolution in high temperature liquids and nucleation in glasses and supercooled liquids

- To synthesize and provide a source for new non-equilibrium materials



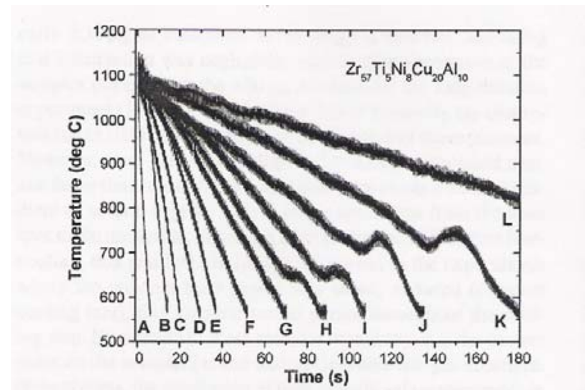
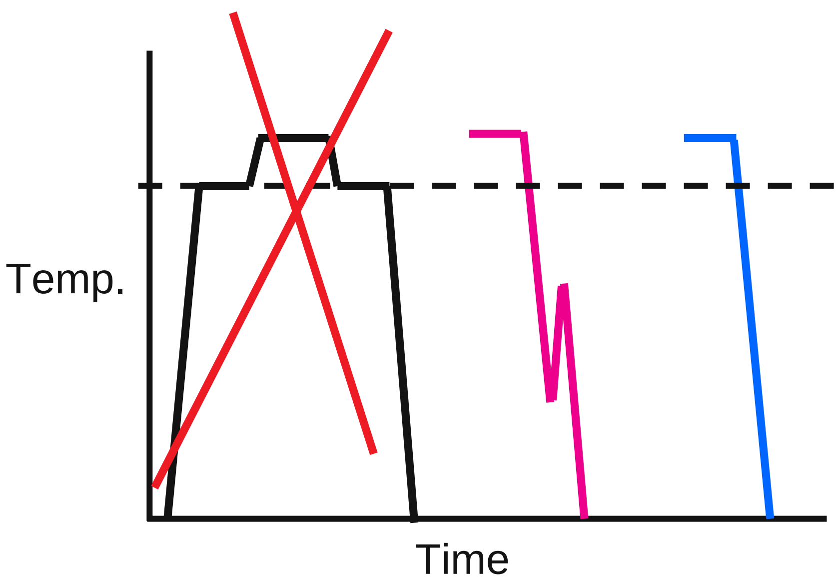
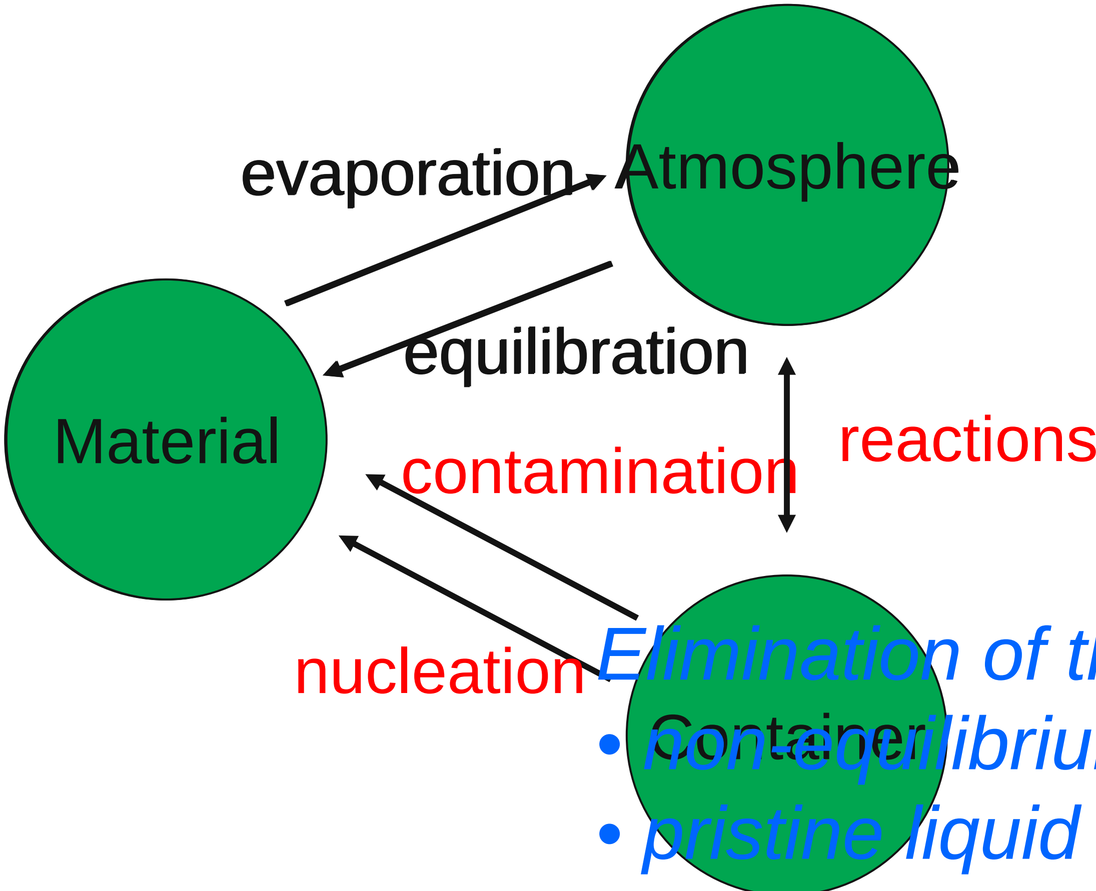




Fig. 2. Time–temperature curves of $Zr_{57}Ti_5Ni_8Cu_{20}Al_{10}$ spheres processed with 69–1.2 K/s cooling rates. The process cooling rates (slopes of the respective curves) are: A, 69 K/s; B, 38 K/s; C, 23 K/s; D, 16 K/s; E, 13 K/s; F, 11 K/s; G, 8 K/s; H, 6 K/s; I, 4.5 K/s; J, 3.5 K/s; K, 2.7 K/s; L, 1.2 K/s (recalesced at $t = 220$ s, $T = 730$ °C). Note that curve "G" exhibits a slight exotherm at ~625 °C, which is not clearly visible in the scale used here.

Wall, *et al*, Mater. Sci. Eng. A, **445-446**, 219-222 (2007).



# Containerless processing/levitation




*Elimination of the container acceses:*

- *non-equilibrium liquids*
- *pristine liquid surfaces*
- *extreme chemical purity*

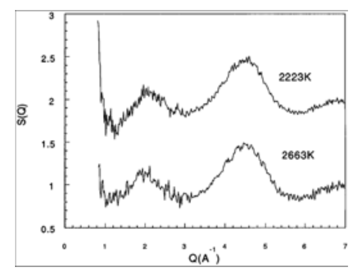
## *Method*

# *F = -mg*

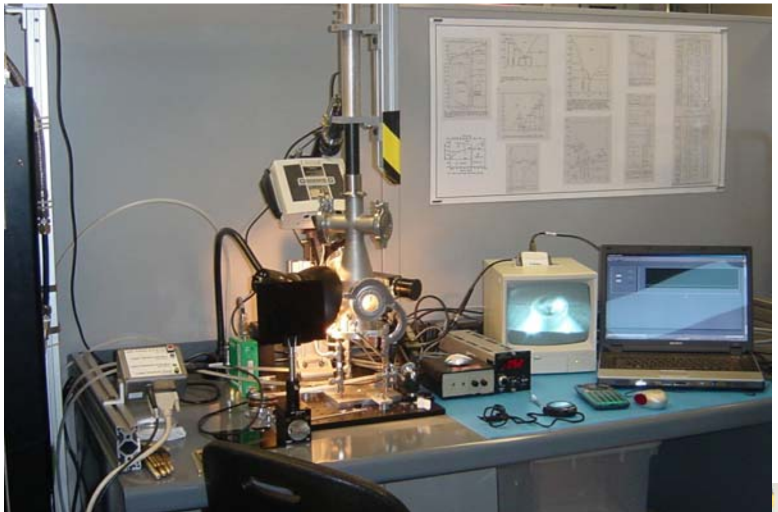
3 mm

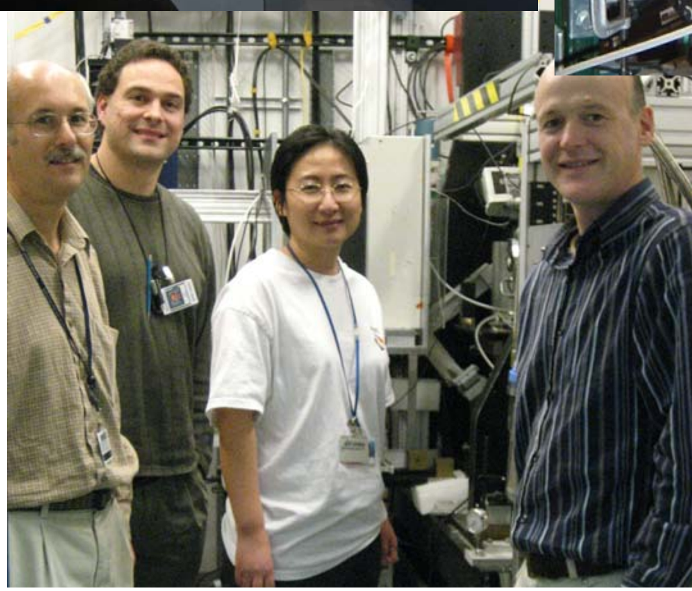
Compact footprint
2 x 2 x 2.5”
(5 x 5 x 6 cm)

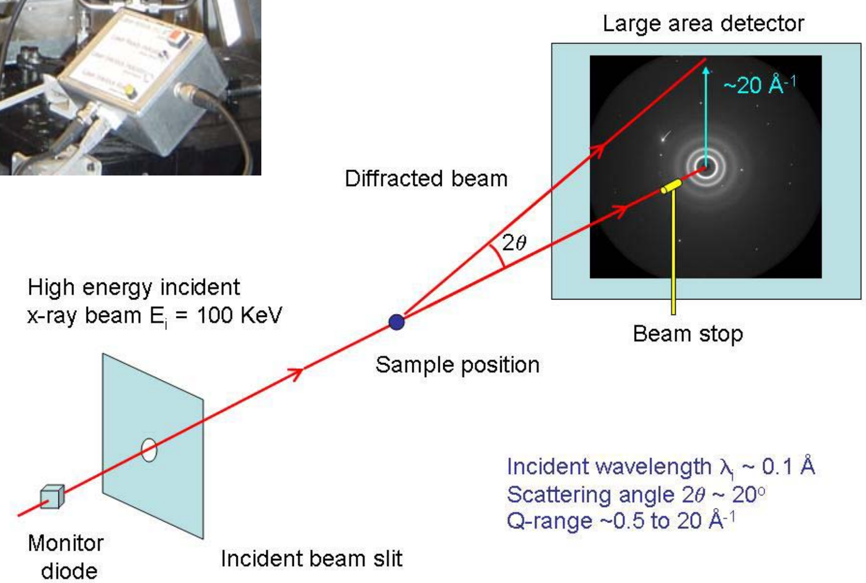
S. Ansell. S. Krishnan, J.K.R. Weber, J.J. Felten, P.C. Nordine, M.A. Beno, D.L. Price and M-L Saboungi, "Structure of Liquid Aluminum Oxide," Phys. Rev. Lett., **78**, 464 (1997).
1995 NSLS X-6B 7keV



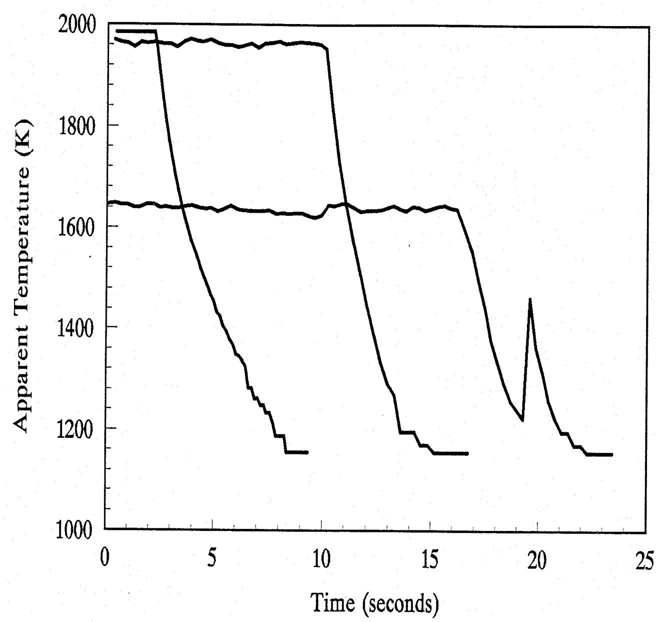
# *Operated as a Class I laser system with embedded 250 Watt (Class IV) $CO_2$ laser in the lab and at 11 ID-C*



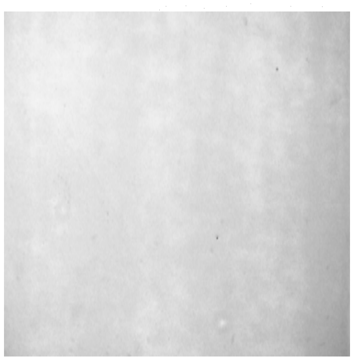




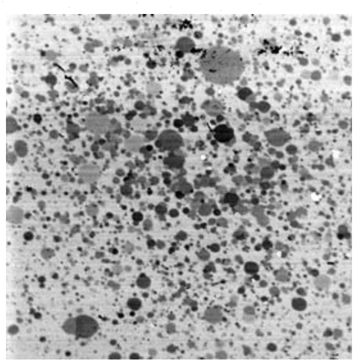
# *Lab-based synthesis facility*



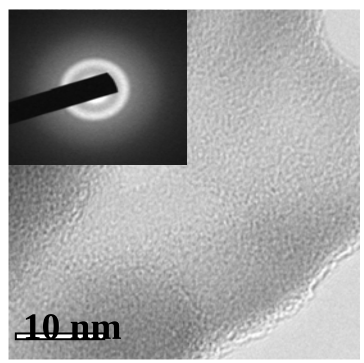




1-phase glass

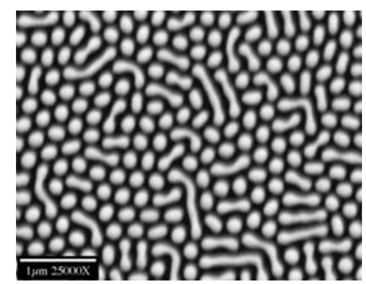


2-phase glass




TEM ht. treated gl.

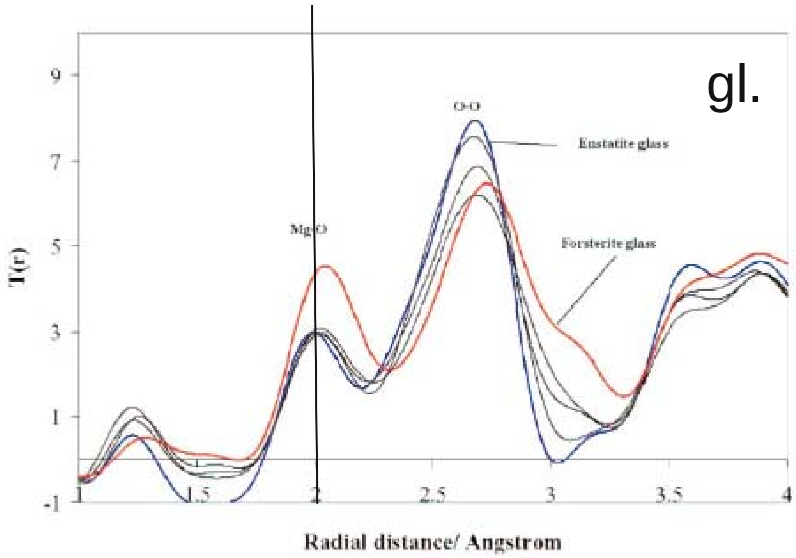
Fibers from u/c liq.

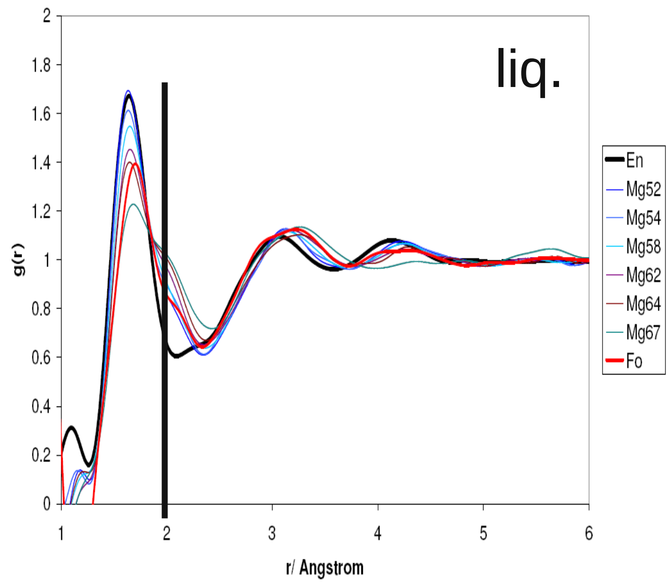


SEM fast sol. liquid

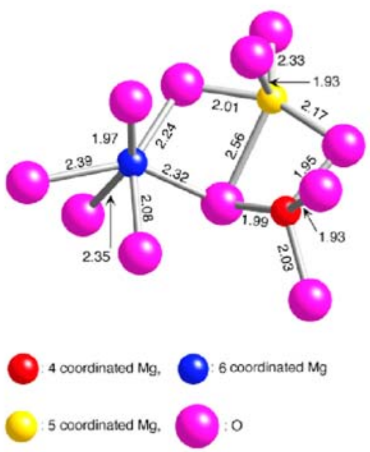
Weber, *et al.* J. Am. Ceram. Soc., **83**, 1868 (2000), Weber, *et al* Nature, 393, 769 (1998).

# Example 1 – Mg-Si-O liquids and glasses



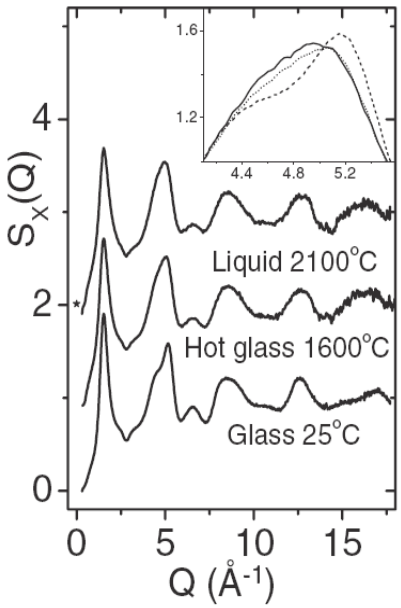

Str. changes in Mg-O network shift to higher $SiO_2$ content in liquids than in glasses – suggests a fragile-strong transition as the cooling liquid restructures

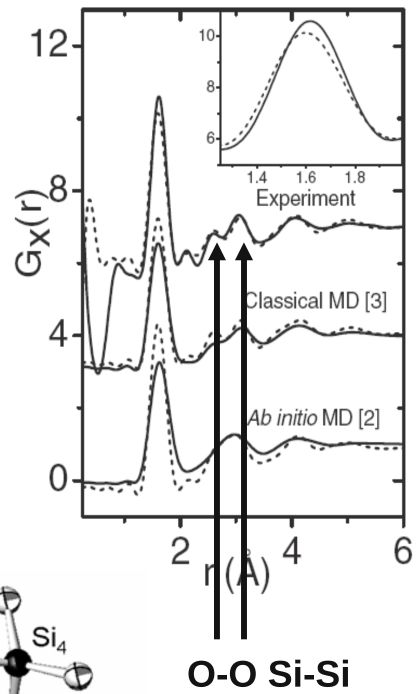


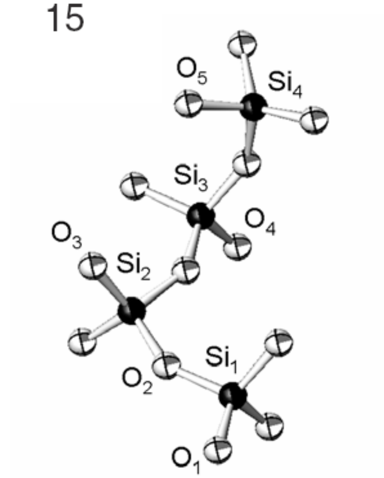


Tangeman, *et al*. GRL, **28**, 2517 (2001),
Kohara, *et al*, Science, **303**, 1649 (2004),
Wilding, *et al*., Europhys. Lett. **67**, 212 (2004).

# *Example 2 – liquid $SiO_2$*




Mei, *et al*, PRL, 98, 057802 (2007).

- Main change is in shape of $2^{nd}$ peak in S(Q)
- Strong FSDP suggests robust network at high T
- Differences 1600-2100$^o$C small 25-1600$^o$C
- 2% increase in Si-O bond length from 25 to 1600$^o$C
- Ave. bond angle decreases ~9$^o$ with T – small changes in polymer ring size

# *Summary and outlook*

- Versatile and compact aerodynamic levitator with Class I laser beam heating demonstrated with oxide, metallic and semiconductor liquids

- Extreme sample environment can access deeply undercooled liquids, allow controlled nucleation of crystallites, *in-situ* oxidation studies, and synthesize novel glassy and NE materials

- High energy, high flux X-rays can probe bulk structure of undercooled liquids *in-situ* but not yet in real time – high *flux* and *fast detection* are needed

- Science/Applications: Structure evolution in liquids with T,X, “nano-nucleation”/crystallization of extreme glasses, dopant ion environment, “ambiguous” polyamorphic/ glacial/quasi-crystal states in non-equilibrium materials

# *Thanks!*

- Funding: Department of Energy, NASA, Brian Toby, APS XSD

- Collaborators:  Beamline experiments: Chris Benmore, Qiang Mei, Argonne, Martin Wilding U. Wales, John Hardy PNNL